Predictions of cell survival along proton spread out Bragg-peaks based on the Local Effect Model

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Introduction: Proton beam radiotherapy is a common clinical treatment procedure. For the clinical practice the biological effectiveness of protons is assumed to be constant (RBE=1.1). Nevertheless, in-vitro studies show that protons have an increased RBE at the end of their range [1, 2]. This increase of the RBE can be explained by the increasing LET at the declining edge of the spread out Bragg-peak (SOBP). The recently published version of the Local Effect Model (LEM IV; [3]) has shown to be applicable for a wide range of particles and energies. In the present work we focus on the comparison of measured cell survival data along proton SOBP with the predicted cell survival of the LEM IV to validate the predictions for further analysis.

Methods: The LEM IV predictions are compared to cell survival of CHO cells after irradiation measured by Tang et al. [1] and for SCC25 cells measured by Bettega et al. [2]. Both used a 65 MeV proton beam to produce an SOBP with 15 mm and 17.5 mm extension, respectively. Cells were irradiated at differnt positions of the SOBP with different doses levels. Irradiations were simulated with the treatment planning software TRiP98 [4]. As input parameters for the LEM IV calculations the RBE-table AB-CHO with the photon parameters given in Tang et al. [1] and the RBE-table AB-SCC25 with photon parameters given in Bettega et al. [2] were used and listed in Tab. 1:

RBE-table	$\alpha\,[\mathrm{Gy}^{-1}]$	$\beta\,[\mathrm{Gy}^{-2}]$	$\alpha/\beta\,[Gy]$	$D_t\,[Gy]$
AB-CHO	0.16	0.0246	6.5	13
AB-SCC25	0.57	0.012	47.5	15

Results: Fig. 1a shows the cell survival measurements from Tang et al. [1] with CHO cells in different depths for 2 Gy also in the entrance channel. Fig. 1b shows the cell survival measurements from Bettega et al. [2] with SCC25 cells in different depths for 2, 5 and 7 Gy. For both data sets the model predictions are in accordance with the experimentally observed survival. In particular, for SCC25 cells the steep increase of RBE values significantly above 1.1 at the distal egde is reproduced by the model predictions very well (Tab. 2), thus clearly demonstrating the relevance of RBE effects at the distal end of the SOBP.

Conclusion: The depth and dose dependence of RBE as predicted by LEM IV for proton SOBPs was shown to be consistent with experimental data. LEM IV thus represents a useful tool to implement variable RBE values in treatment planning for protons, aiming at overcoming limitations that might result from the currently used constant RBE value of 1.1 for clinical applications.

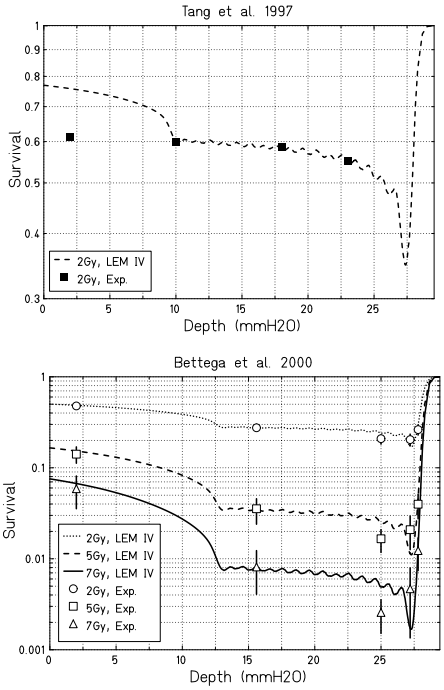

Figure 1: a) Comparison of measured and predicted cell survival (LEM IV) for a) CHO cells [1] for 2 Gy physical dose and b) SCC25 cells [2] for 2, 5 and 7 Gy physical dose at different positions of the SOBP (symbols). The lines correspond to the predictions of LEM IV.

Table 2:

Position	Dose	RBE exp. Bettega [2]			LEM prediction		
(mm)	(%)	2 Gy	5 Gy	7 Gy	2 Gy	5 Gy	7 Gy
2	65	1.00	1.00	1.00	0.97	0.97	0.98
15.6	100	1.058	1.043	1.035	1.071	1.058	1.056
25	101.5	1.23	1.23	1.23	1.18	1.15	1.13
27.2	91	1.39	1.30	1.26	1.42	1.35	1.31
27.8	52	2.064	1.95	1.89	1.79	1.70	1.65

References

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